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(54) **PNEUMATIC ENGINE SYSTEM WITH AIR CIRCULATION**

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(51) **Int. Cl.**

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F01L 1/00	(2006.01)
F01B 31/00	(2006.01)
F04B 1/00	(2006.01)
F01L 1/06	(2006.01)
F01L 5/04	(2006.01)

(52) **U.S. Cl.**

CPC ***F01B 17/02*** (2013.01); ***F01B 31/00*** (2013.01); ***F04B 1/00*** (2013.01); ***F01L 1/00*** (2013.01); *F01L 1/06* (2013.01); *F01L 5/04* (2013.01)

(58) **Field of Classification Search**

CPC F01B 17/02; F01B 31/00; F04B 1/00; F01L 1/00; F01L 1/06; F01L 5/04; F15B 1/027

USPC 60/407, 412

See application file for complete search history.

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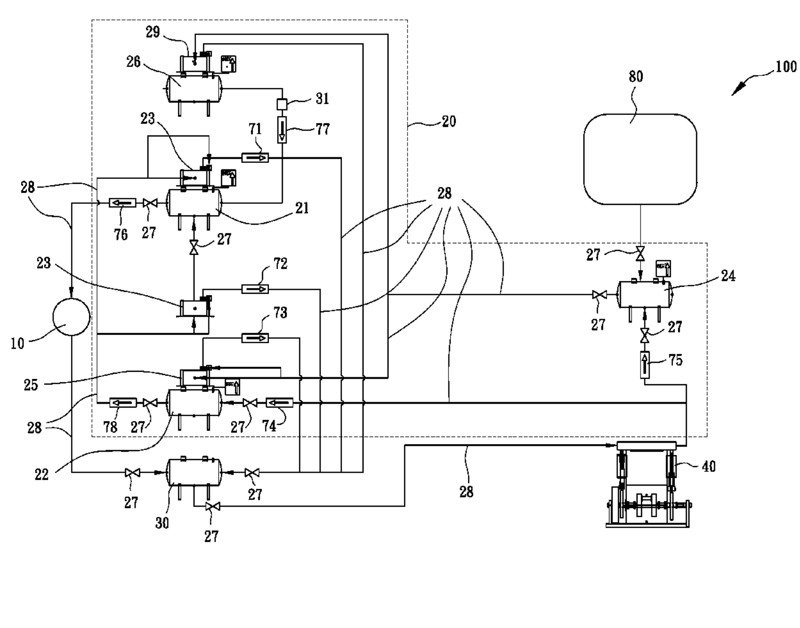
(57) **ABSTRACT**

A pneumatic engine system uses gas circulation to recycle exhausted air, so as to reduce gas consumption, save energy, protect the environment, operate for a longer duration, and slow down the attenuation of the power output thereof. The pneumatic engine system includes a pneumatic engine, a gas storage device, a transit gas storage tank, and a suction device. The pneumatic engine receives a compressed air to generate power output. The gas storage device stores the compressed gas and supplies the compressed gas to the pneumatic engine. The transit gas storage tank receives gas discharged from the pneumatic engine. The suction device extracts gas from the transit gas storage tank and transport the extracted gas to the gas storage device for recycle.

6 Claims, 7 Drawing Sheets



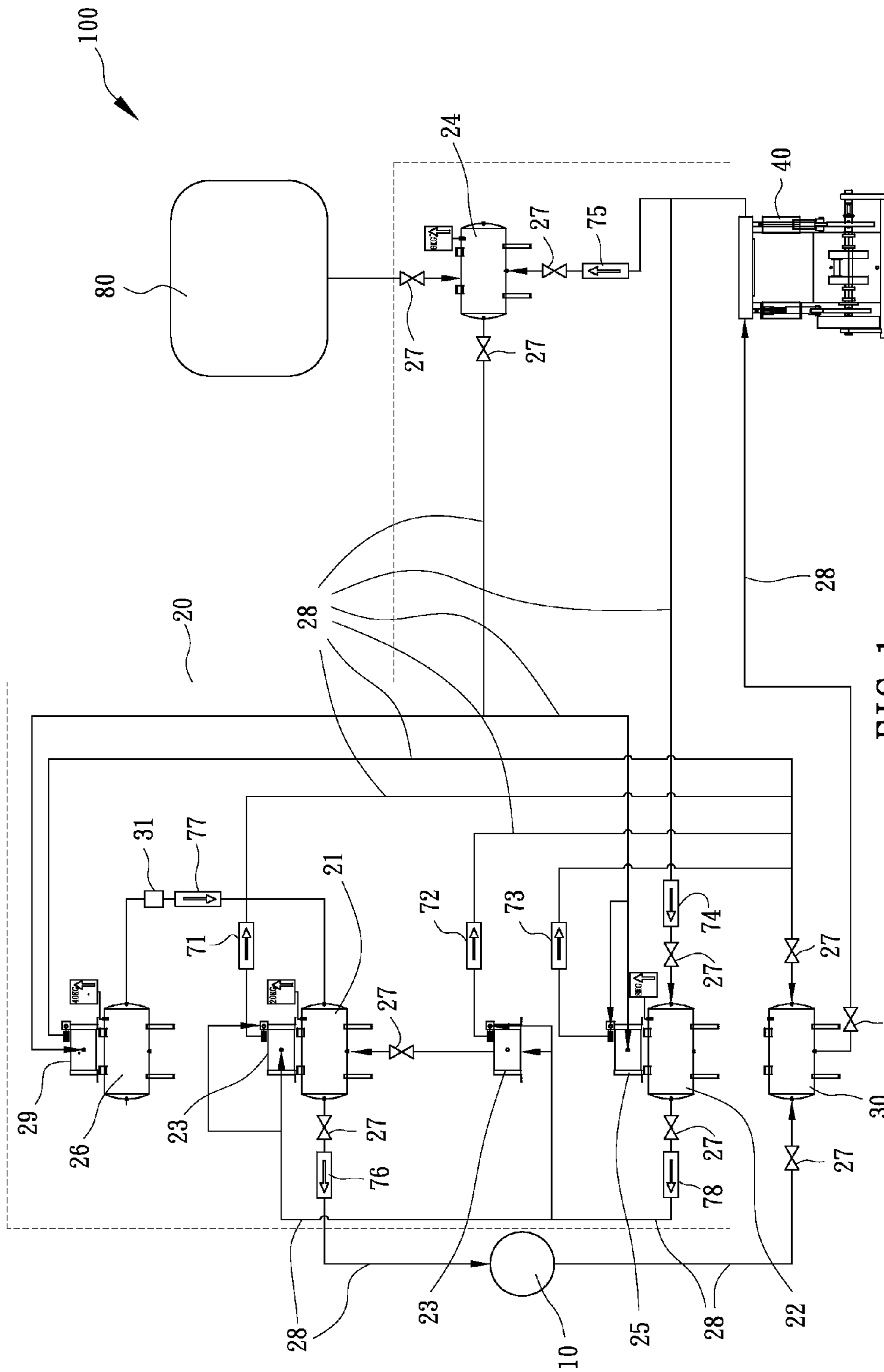


FIG. 1

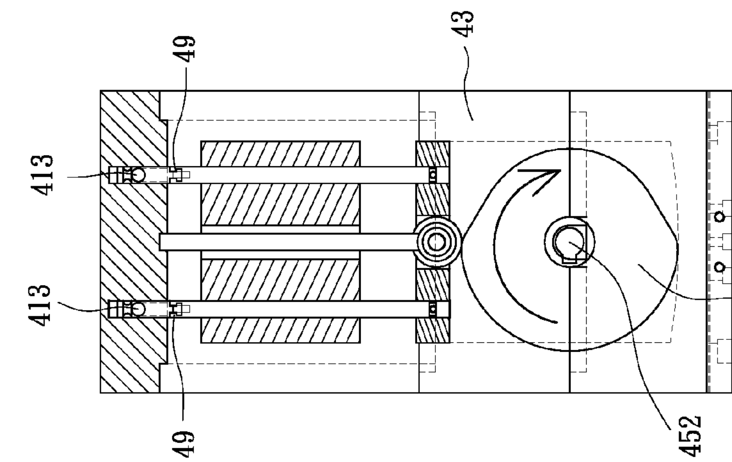


FIG. 4

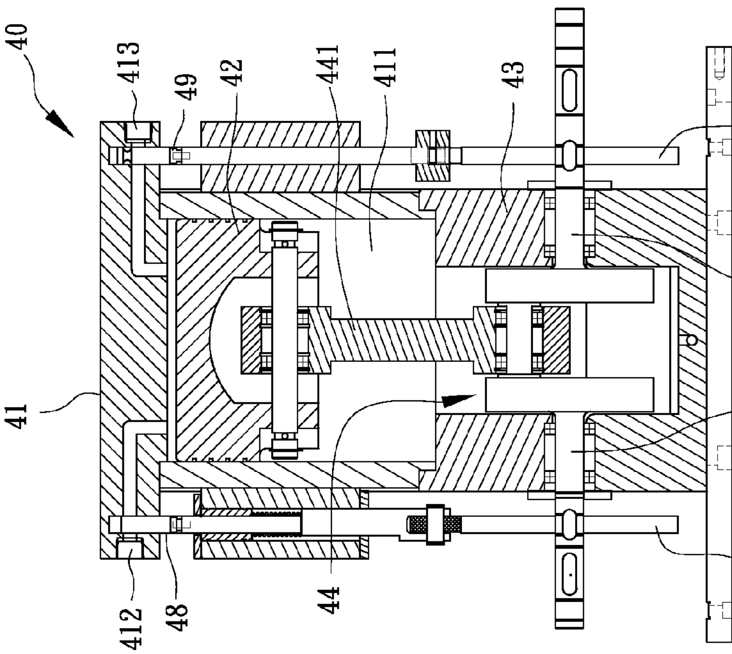


FIG. 2

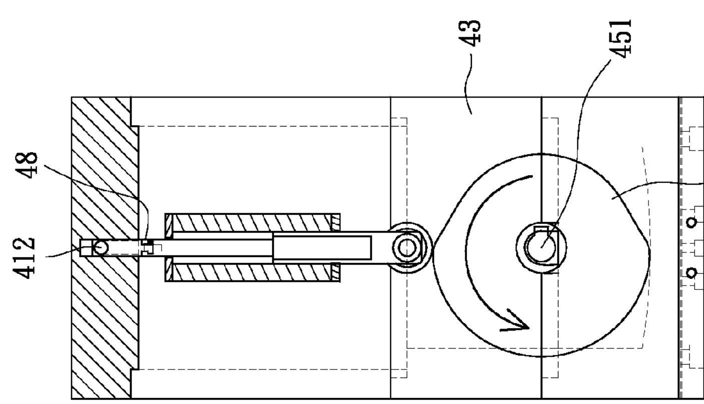


FIG. 3

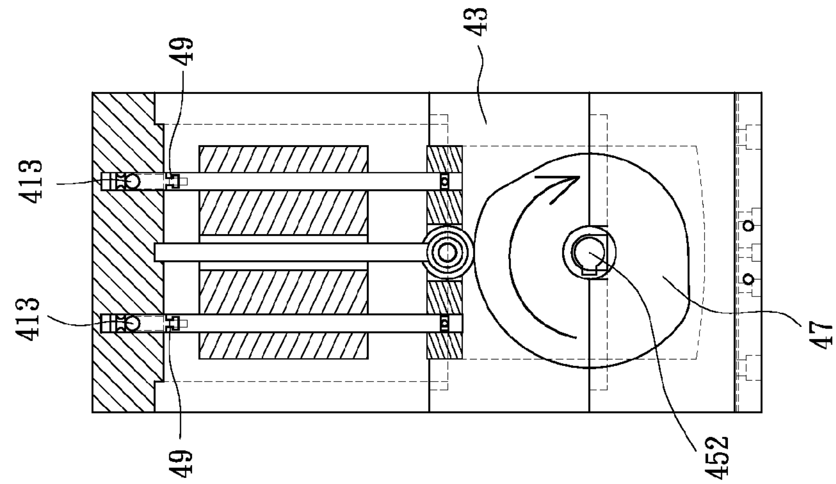


FIG. 7

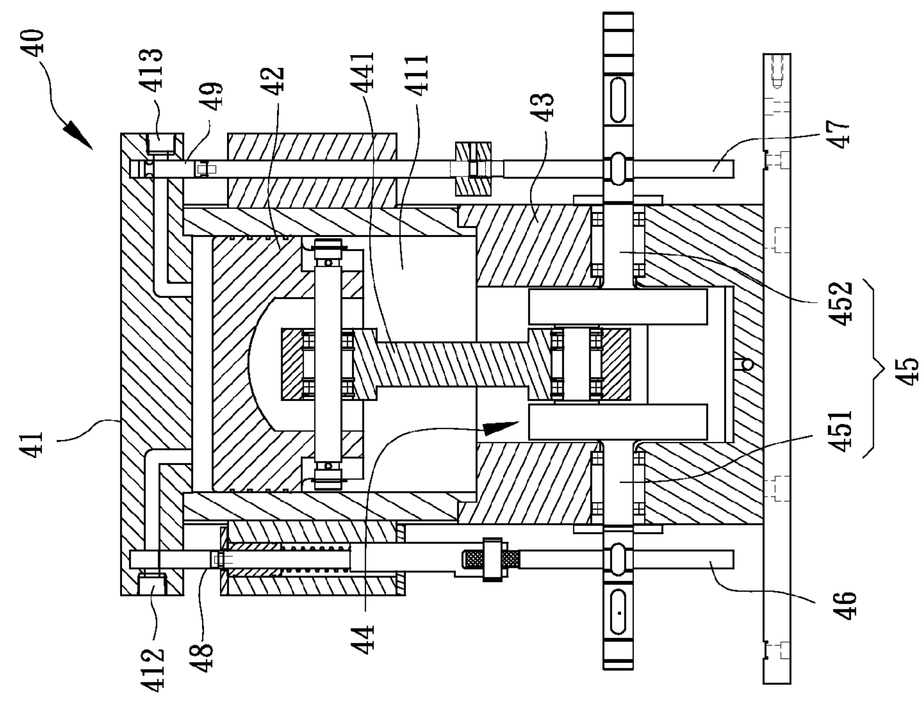


FIG. 5

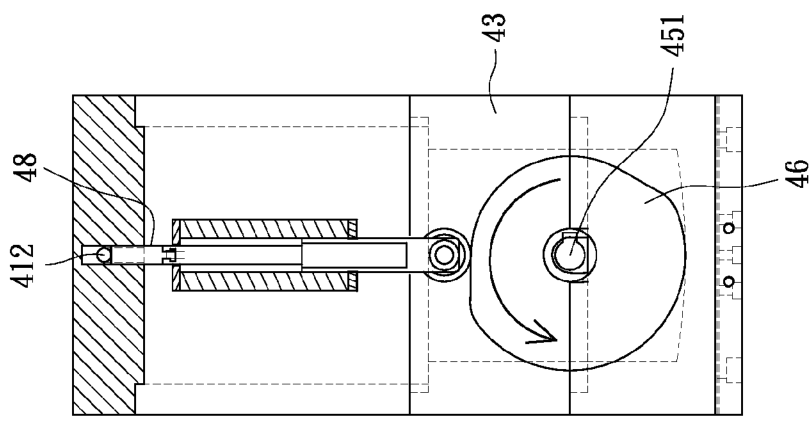


FIG. 6

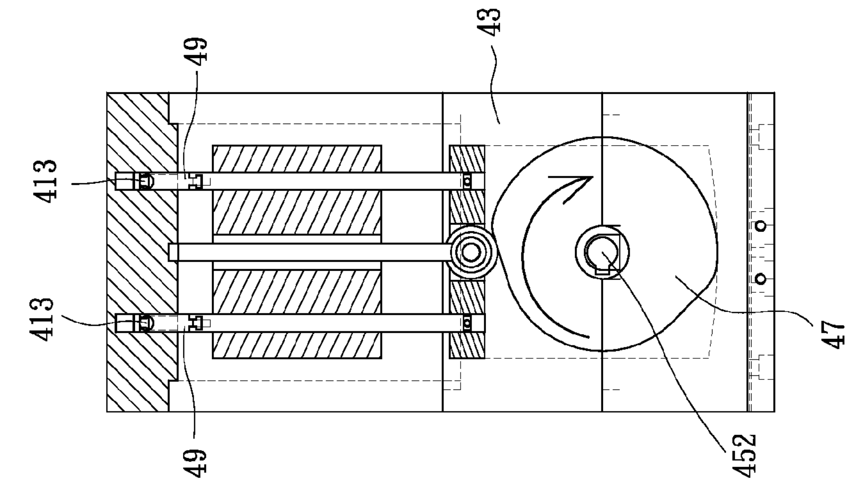


FIG. 10

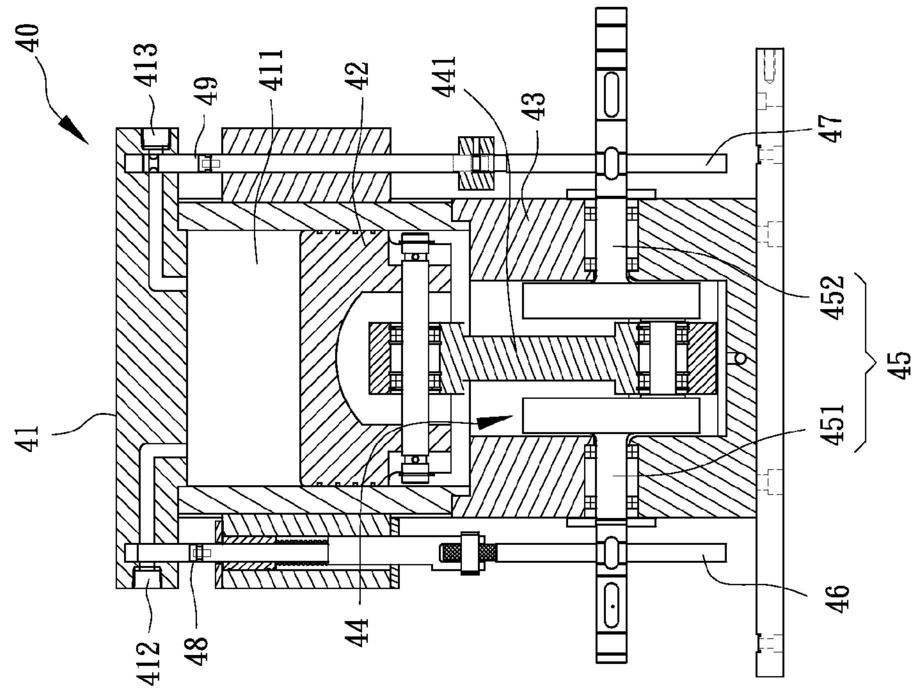


FIG. 8

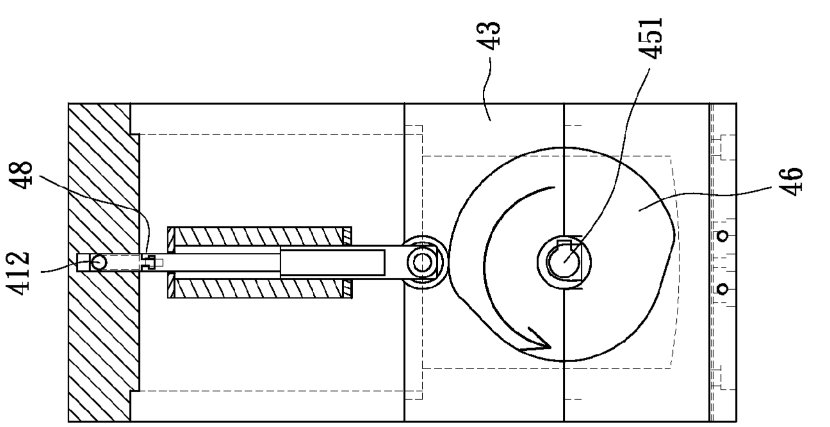


FIG. 9

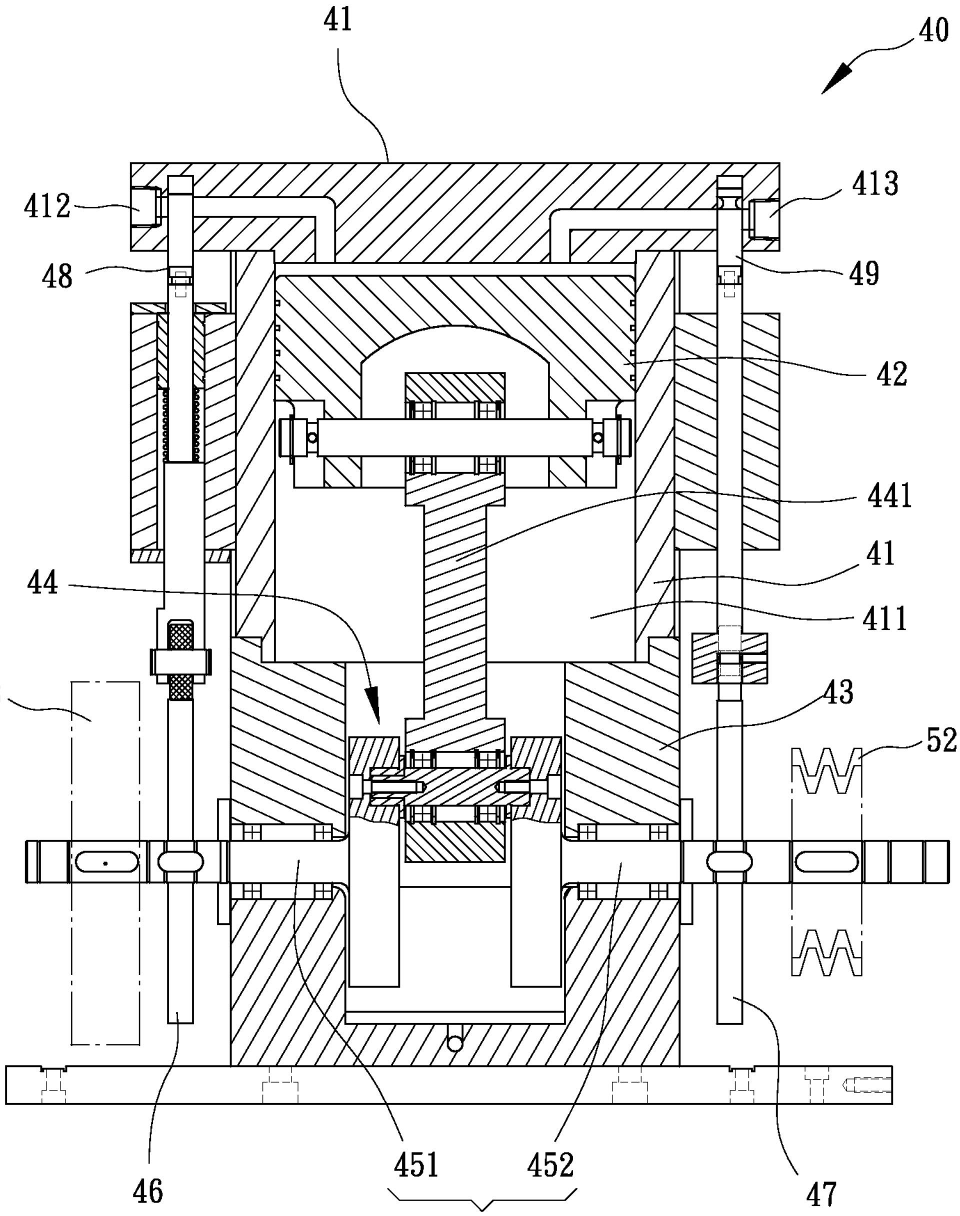


FIG. 11

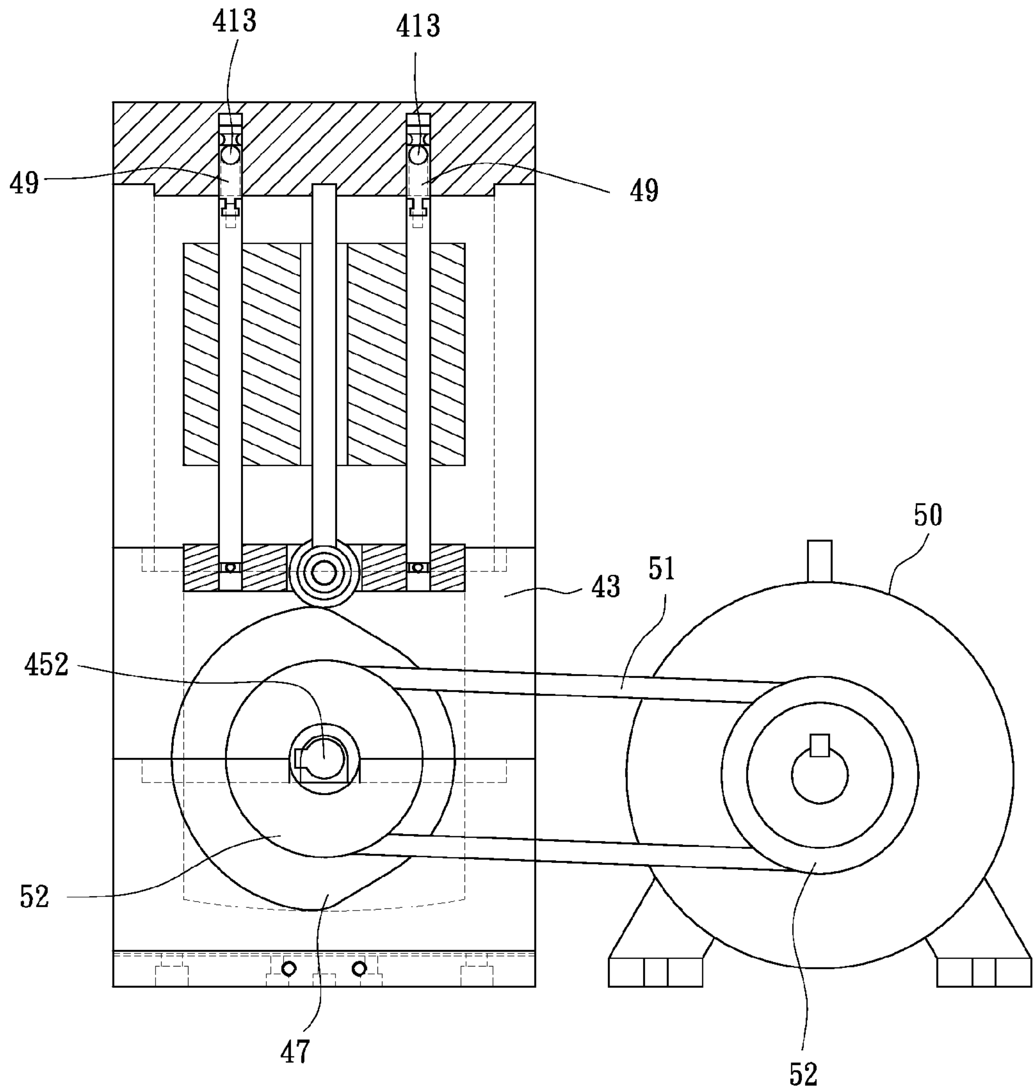


FIG. 12

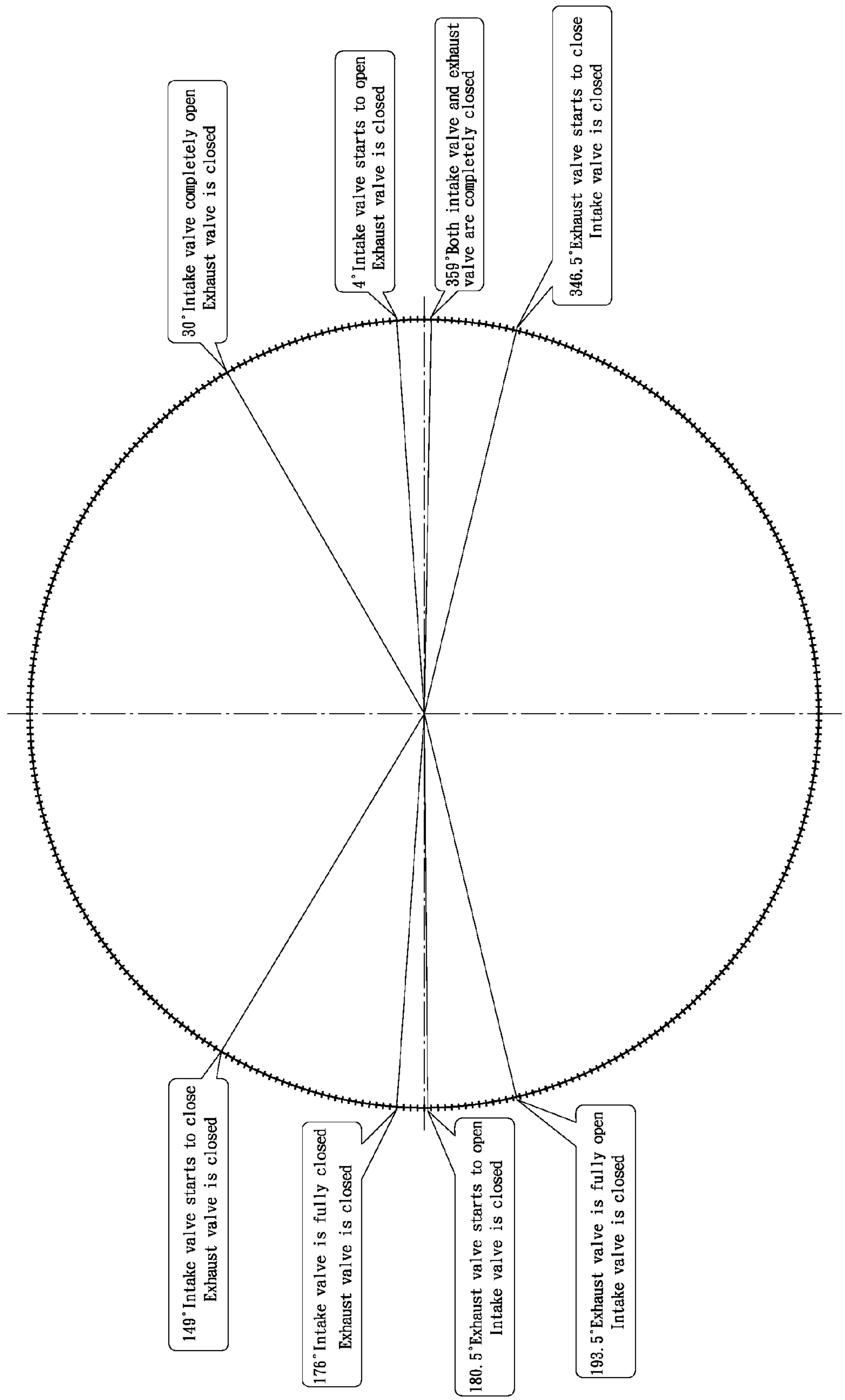

30°Intake valve completely open
Exhaust valve is closed
4°Intake valve starts to open
Exhaust valve is closed
359°Both intake valve and exhaust valve are completely closed
346.5°Exhaust valve starts to close
Intake valve is closed
149°Intake valve starts to close
Exhaust valve is closed
176°Intake valve is fully closed
Exhaust valve is closed
180.5°Exhaust valve starts to open
Intake valve is closed
193.5°Exhaust valve is fully open
Intake valve is closed

FIG. 13

PNEUMATIC ENGINE SYSTEM WITH AIR CIRCULATION

BACKGROUND

1. Technical Field

The present application relates to a pneumatic power apparatus, and more particularly, to a gas engine system with air circulation.

2. Related Art

Invention of the internal combustion engine drove Industrial Revolution and brought flourish development in human civilization. However, the internal combustion engine using fossil fuels produces carbon dioxide after combustion. In addition to causing air pollution, the greenhouse effect and global warming, carbon dioxide has already endangered the survival of human and biological. Pneumatic engine mainly makes use of high pressure air to transforming gas into rotation power. Since its discharge is also air, there are no foul odor and no pollution. Cost is also lower than gasoline and diesel. Therefore, the pneumatic engine is a good power generation choice. The use of high pressure gas of pneumatic engine is from a high pressure gas cylinder where gas is compressed. Gas consumption of pneumatic engine is in a large volume. High pressure gas cylinder to supply pneumatic engine cannot last long. This causes the power output from pneumatic engine to attenuate; and consequently, the pneumatic engine cannot continue to operate. It is thus an important topic to reduce gas consumption with the same amount of gas supply, so as to increase the operation duration of the engine and slow down the attenuation of the power output.

BRIEF SUMMARY

A pneumatic engine system with gas circulation operable to reduce gas consumption rate is provided. The pneumatic engine system with gas circulation allows gas exhausted from the engine to be recycled to solve the problem of traditional gas supply by the high pressure gas cylinders. This system comprises a pneumatic engine, a gas storage device, a transit gas storage tank, and a suction device. The pneumatic engine accepts a compressed gas to produce power output. The gas storage device stores the compressed gas and provides it to the pneumatic engine. The transit gas storage tank retrieves a gas discharged from the pneumatic engine. The suction device extracts gas from the transit gas storage tank and delivers the extracted gas to the gas storage device. Then gas can thus be recycled.

The gas storage device comprises three gas tanks. The first gas tank is used to store the compressed gas and to provide the compressed gas to the pneumatic engine. The second gas tank also stores the compressed gas. The pressure in the second gas tank is less than the pressure in the first gas tank. Therefore, a first booster pump located between the first and second gas tank is used to pressurize output gas from the second gas tank. The pressurized compressed gas is then delivered to the first gas tank. The third gas tank stores the compressed gas and the pressure in the third gas tank is less than the pressure in the second gas tank. A second booster pump located between the second and third gas tanks is used to pressurize gas output from the third gas tank. The pressurized gas is stored in the second gas tank. Gas discharged from the first and second booster pumps output to the transit gas tank for recycling. The suction device transports the recycled gas from the transit gas storage tank to the second and third gas tanks.

In some embodiments, a pneumatic engine system may further comprise an air compressor/gas storage cylinder set. When the pressure in the third gas tank is insufficient, the air compressor/gas storage cylinder set supplements the pressure in the third gas tank.

The suction device comprises a cylinder block possessing piston cylinder. The piston cylinder has an intake valve and an exhaust valve. A piston moves in the piston cylinder. A crank chamber is provided in one side of the piston cylinder. Crank member located in the crank chamber and the piston are pivotally connected together by a connecting rod. When the crank member is rotated, the piston in the piston cylinder moves up and down. A spindle structure having a right spindle and a left spindle is provided. The left spindle located in crank chamber is pivotally connected to crank members and protrudes from one side of crank chamber. The right spindle located in the crank chamber is pivotally connected to the crank member and protrudes from the other side of crank chamber. The left and right spindles rotate synchronously. An intake cam is fixed on the left spindle and an exhaust cam is fixed on the right spindle. An intake switch in the intake valve opens or closes the intake valve by means of the intake cam. An exhaust switch in the exhaust valve opens or closes the exhaust valve by means of the exhaust cam. A motor drives the spindle to rotate and makes the intake valve and the exhaust valve open or close. The spindle also drives the piston to move up and down. Gas enters into the transit gas storage tank from the intake valve and discharges from the exhaust valve through piston compression.

Gas discharged from the pneumatic engine, the first booster pump, the second booster pump, and the third booster pump has residual pressure. This discharged gas will be recycled to the transit gas storage tank. The suction device is used to withdraw the gas to the second and third gas tanks. The recycled residual pressure can reduce gas consumption. In addition to energy saving and environmental protection, the present application also allows the pneumatic engine to maintain a longer running time and reduce attenuation speed of power output.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other features and advantages of the various embodiments disclosed herein will be better understood with respect to the following description and drawings, in which like numbers refer to like parts throughout, and in which:

FIG. **1** is a system configuration diagram for the pneumatic engine system using gas circulation;

FIG. **2** is a cross-sectional view of the suction device in the pneumatic engine and displays the spindle in the initial state;

FIG. **3** is a side view of FIG. **2**;

FIG. **4** is another side view of FIG. **2**;

FIG. **5** is a cross-sectional view of the suction device in the pneumatic engine and displays the spindle rotating 30 degree;

FIG. **6** is a side view of FIG. **5**;

FIG. **7** is another side view of FIG. **5**;

FIG. **8** is a cross-sectional view of the suction device in the pneumatic engine and displays the spindle rotating 193.5 degree;

FIG. **9** is a side view of FIG. **8**;

FIG. **10** is another side view of FIG. **8**;

FIG. **11** is a cross-sectional view of the suction device in the pneumatic engine and also shows the idler and pulley;

FIG. **12** is a cross-sectional view displaying the pneumatic engine and motor;

FIG. **13** is a relational diagram showing rotation angles of the spindle, intake valve and exhaust valve in the pneumatic engine.

DETAILED DESCRIPTION

Referring to FIG. **1**, a pneumatic engine system with gas circulation **100** including the pneumatic engine **10**, the gas storage device **20**, the transit gas storage tank **30** and the suction device **40** is provided.

The pneumatic engine **10** accepts compressed gas to produce power output. This is a way to convert compression energy of gas into kinetic energy. The pneumatic engine used in this embodiment is a power apparatus such as U.S. Pat. No. 7,866,251 B2 (corresponding cases include PCT/CN2007/001994, CN665571, and TWI327621, which are incorporated by reference by its entirety). The gas storage device **20** can store the compressed gas and provide it to the pneumatic engine **10**. The gas storage device **20** in this embodiment includes the first gas tank **21**, the second gas tank **22**, the first booster pump **23**, the third gas tank **24** and the second booster pump **25**. The first gas tank **21** stores the compressed gas and supplies it to the pneumatic engine **10**. The second gas tank **22** also stores the compressed gas. The pressure in the second tank **22** is less than the pressure in the first gas tank **21**. Therefore, the first booster pump **23** located between the first gas tank **21** and the second gas tank **22** is used to pressurize output gas from the second gas tank **22**. The pressurized compressed gas is then delivered to the first gas tank **21**. There are two first booster pumps **23** used in this embodiment. The third gas tank **24** stores compressed gas and the pressure in this tank is less than the pressure in the second gas tank **22**. The second booster pump **25** located between the second gas tank **22** and the third gas tank **24** is used to pressurize gas output from the third gas tank **24**. The pressurized gas is stored in the second gas tank **22**.

In FIG. **1**, the gas storage device **20** includes a high pressure gas supplement tank **26**, the third booster pump **29** and a regulator valve **31**. The high pressure gas supplement tank **26** is for the storage of compressed gas and the pressure is greater than the pressure in the first gas tank **21**. When pressure in the first gas tank is below the set value, the regulator valve **31** is opened. The high pressure gas supplement tank **26** replenishes pressurized gas to the first gas tank **21**. The regulator valve **31** is closed to stop supplying gas until the pressure in the first gas tank **21** is higher than the set value. The third booster pump **29** located between high pressure supplement tank **26** and the third gas tank **24** is used to pressurize output gas from the third gas tank **24**. The pressurized compressed gas is then delivered to the high pressure supplement tank **26**.

As described above, gas discharged from the pneumatic engine **10**, the first booster pump **23**, the second booster pump **25** and the third booster pump **29** still has residual pressure. The transit gas storage tank **30** is used to retrieve gas discharged. The suction device **40** is used to withdraw gas discharged to the second gas tank **22** and/or the third gas tank **24** in the gas storage device **20**. The recycled residual pressure can reduce gas consumption. In addition to energy saving and environmental protection, the present application also allow the pneumatic engine to maintain a longer running time and reduce attenuation speed of power output.

The check valves **71**, **72**, **73** are installed in the first booster pump **23**, the second booster pump **25** and the transit gas storage tank **30**, respectively. The check valve **74** and **75** are installed between the suction device **40**, the second gas tank **22**, and the third gas tank **24**. The check valve **76** is installed between the first gas tank **21** and the pneumatic engine. The check valve **78** is installed between the second gas tank **22** and the first booster pump **23** and the check valve **77** is located between the high pressure gas supplement tank **26** and the first gas tank **21**. The check valves are operable to avoid gas reversing.

Referring to FIGS. **2** to **12**, the suction device **40** in this embodiment includes a cylinder block **41**, a piston **42**, a crank chamber **43**, a crank member **44**, a spindle **45**, an intake cam **46**, an exhaust cam **47**, an intake switch **48**, an exhaust switch **49** and a motor **50**.

The cylinder block **41** includes the piston cylinder **411**, which has the intake valve **412** and the exhaust valve **413**. The piston **42** is located and operable to move in the piston cylinder **411**. The crank chamber **43** is provided at one side of the piston cylinder **411**. In this embodiment, the crank chamber is located on the bottom side. The crank member **44** is disposed in crank chamber **43**. The crank member **44** has a connecting rod **441**. The crank member **44** and the piston **42** are pivotally connected together by the connecting rod **441**. When the crank member **44** is rotated, the piston **42** in the piston cylinder **411** moves up and down. In this embodiment, the spindle **45** having a left spindle **451** and a right spindle **452** is provided. The left spindle **451** located in the crank chamber **43** is pivotally connected to the crank member **44** and protrudes from one side of crank chamber **43**. The right spindle **452** located in the crank chamber **43** is pivotally connected to the crank member **44** and protrudes from the other side of crank chamber **43**. The left spindle and right spindle rotates synchronously. The intake cam **46** is fixed on the left spindle **451** and the exhaust cam **47** is fixed on the right spindle **452**. In addition, the intake switch **48** located in the intake valve **412** opens or closes the intake valve **412** by means of the intake cam **46**. The exhaust switch **49** located in the exhaust valve **413** opens or closes the exhaust valve **413** by means of the exhaust cam **47**.

The motor **50** drives the spindle **45** to rotate and makes the intake valve **412** and the exhaust valve **413** open or close. The spindle **45** also drives the piston **42** to move up and down. Gas enters into the transit gas storage tank **30** from the intake valve **412** and discharges from the exhaust valve **413** through the piston **42** compression. In the embodiment as shown in FIGS. **11** and **12**, rotation of the right spindle **452** in the spindle **45** is driven by the motor **50** through the belt **51** and the pulley **52**. In addition, the left spindle **451** has an idler **53**. The moment of inertia from the idler **53** assists the operation of the suction device **40**.

Referring to FIG. **13**, the piston **42** as shown in FIGS. **2-4** is at the highest point for the beginning of a cycle. The intake valve **412** and the exhaust valve **413** are in the close state. When the spindle **45** rotates to about 4°, the intake valve **412** starts to open and the exhaust valve **413** is still in the closed state. Referring to FIGS. **5** to **7**, when the spindle **45** rotates to about 30°, the intake valve **412** is fully open and the exhaust valve is still in the closed state. While the piston **42** goes down, gas enters into the piston cylinder **411**. When the spindle **45** rotates to about 149°, the intake valve **412** starts to close and the exhaust valve still remains in the closed state. When the spindle **45** rotates to about 176°, the intake valve **412** is fully closed and the exhaust valve **413** is still in the closed state. When the spindle **45** rotates to about 180.5°, the exhaust valve **413** starts to open and the intake valve **412** is closed. The piston **42** starts to rise and gas is then pushed out. Referring to FIGS. **8** to **10**, when the spindle **45** rotates to about 193.5°, the exhaust valve **413** is fully open and the intake valve **412** is closed. When the spindle **45** rotates to about 346.5°, the exhaust valve **413** starts to close and the intake valve **412** is still in the closed state. When the spindle **45** rotates to about 359°, both the intake valve **412** and the exhaust valve **413** are closed. When the piston **42** reaches the highest point, gas in the piston cylinder **42** is pushed out completely. When the spindle **45** rotates to about 360°, both the intake valve **412** and the exhaust valve **413** are closed. A full cycle of piston **42** has been completed. Gas in the transit gas storage tank **30** can be effectively pumped into the second gas storage tank **22** and the third gas storage tank **24** by the suction device **40**.

This embodiment further comprises an air compressor/gas storage cylinder set **80**. When the third gas tank **24** is insufficient pressure, the air compressor/gas storage cylinder set **80** supplements the pressure in the third gas tank **24**.

In FIG. **1**, a switch valve **27** is provided to a pipeline **28** which is used to connect the first gas tank **21**, the second gas tank **22** and the third gas tank **24**. The switch valve **27** can open and close the external path and can also be conveniently inflated in advance for the first gas tank **21**, the second gas tank **22** and the third gas tank **24**.

Operation instructions for this embodiment are as follows. Firstly, the high pressure gas supplementary tank **26**, the first gas tank **21**, the second gas tank **22** and the third gas tank **24** are filled with sufficient gas. In this embodiment, the pressure in the high pressure gas supplementary tank **26** should be maintained between about 25 kg/cm^2 and about 40 kg/cm^2. The pressure in the first gas tank **21** is at about 16 kg/cm^2. The pressure of the second gas tank **22** is at about 8 kg/cm^2. The pressure of the third gas tank **24** is at about 6 kg/cm^2. When the pneumatic engine **10** opens, the first gas tank **21** starts to supply gas. Gas discharged from the pneumatic engine **10** is recycled by he the transit gas storage tank **30** and the suction device **40** withdraws gas discharged to the second gas tank **22** or/and the gas tank **24** for recycling. After the second booster pump **25** pressurizes the gas from the third gas tank **24**, the pressurized gas is then sent to the second gas tank **22**. After the first booster pump **23** pressurizes gas discharged from the second gas tank **22**, the pressurized gas discharged is sent to the first gas tank for recycling. When the pressure of the first gas tank **21** is insufficient, the high pressure gas supplementary tank **26** is responsible for replenishing. Gas discharged in the first booster pump **23**, the second booster pump **25** and the third booster pump is all sent to the transit gas storage tank **30** to complete a recycling loop. Of course, the air compressor/gas storage cylinder set **80** should replenish gas if any gas consumption occurs during this time period. Therefore, this embodiment attenuates gas consumption to a minimum level by using recycling gas.

The above description is given by way of example, and not limitation. Given the above disclosure, one skilled in the art could devise variations that are within the scope and spirit of the invention disclosed herein, including configurations ways of the recessed portions and materials and/or designs of the attaching structures. Further, the various features of the embodiments disclosed herein can be used alone, or in varying combinations with each other and are not intended to be limited to the specific combination described herein. Thus, the scope of the claims is not to be limited by the illustrated embodiments.

What is claimed is:

1. A pneumatic engine system with gas circulation, comprising:

a pneumatic engine receiving a compressed gas to produce power output;

a gas storage device storing the compressed gas and supplying the compressed gas to the pneumatic engine;

a transit gas storage tank recycling a gas discharged from the pneumatic engine; and

a suction device transporting the gas recycled by transit gas storage tank to the gas storage device,

wherein the gas storage device comprises:

a first gas tank storing the compressed gas and providing the compressed gas to the pneumatic engine;

a second gas tank storing the compressed gas, wherein a pressure in the second gas tank is less than a pressure in the first gas tank;

a third gas tank storing the compressed gas, wherein a pressure in the third gas tank is less than the pressure in the second gas tank;

a first booster pump located between the first gas tank and the second gas tank for pressurizing the compressed gas output from the second gas tank and supplying the pressurized compressed gas to the first gas tank;

a second booster pump located between the second gas tank and the third gas tank for pressurizing the compressed gas output from the third gas tank and supplying the pressurized compressed gas to the second gas tank;

wherein gases discharged from the first booster pump and the second booster pump are transported to the transit gas storage tank for recycling; and

the suction device is configured to withdraw gas from the transit gas tank and transport the withdrawn gas to the second gas storage tank and/or the third gas storage tank.

2. The system of claim **1**, further comprising an air compressor and gas cylinder set for supplementing pressure to the third gas tank when a pressure in the third gas tank is insufficient.

3. The system of claim **1**, wherein the suction device comprises:

a cylinder block possessing a piston cylinder and the piston cylinder having an intake valve and an exhaust valve;

a piston located in the piston cylinder and moved in the piston cylinder;

a crank chamber provided in one side of the piston cylinder;

a crank member, having a connecting rod to pivotally connect the piston together, located in the crank chamber to make the piston in the piston cylinder move up and down by means of its rotation;

a spindle having a left spindle located in the crank chamber pivotally connected to the crank member and protruded from one side of the crank chamber and a right spindle located in the crank chamber pivotally connected to the crank member and protruded from the other side of crank chamber, wherein the left and right spindle rotates synchronously;

an intake cam fixed on the left spindle;

an exhaust cam fixed on the right spindle;

an intake valve, having an intake switch, opened or closed by an intake cam;

an exhaust valve, having an exhaust switch, opened or closed by an exhaust cam;

a motor driving the spindle to rotate the piston to move up and down and also making the intake valve and exhaust valve open or close, wherein gas enters into the transit gas storage tank from the intake valve and discharges from the exhaust valve by the piston compression.

4. The system of claim **1**, further comprising two first booster pumps to pressurize gas discharged from the second gas tank and then supply the pressurized gas to the first gas tank.

5. The system of claim **1**, further comprising:

a high pressure gas supplement tank storing the compressed gas in order to replenish the compressed gas to the first gas tank, wherein the pressure in the high pressure gas supplement tank is greater than the pressure in the first gas tank; and a regulator valve opened or closed according to the pressure in the first gas tank below or above the set value.

6. The system of claim **5**, further comprising a third booster pump located between a high pressure supplement tank and the third gas tank to pressurize the gas from the third gas tank and then deliver the pressurized gas to the high pressure supplement tank.

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